Radiation of Gd and Tb plasmas in 6.x nm spectral region

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Motivation

Opportunities for 6.x nm lithography

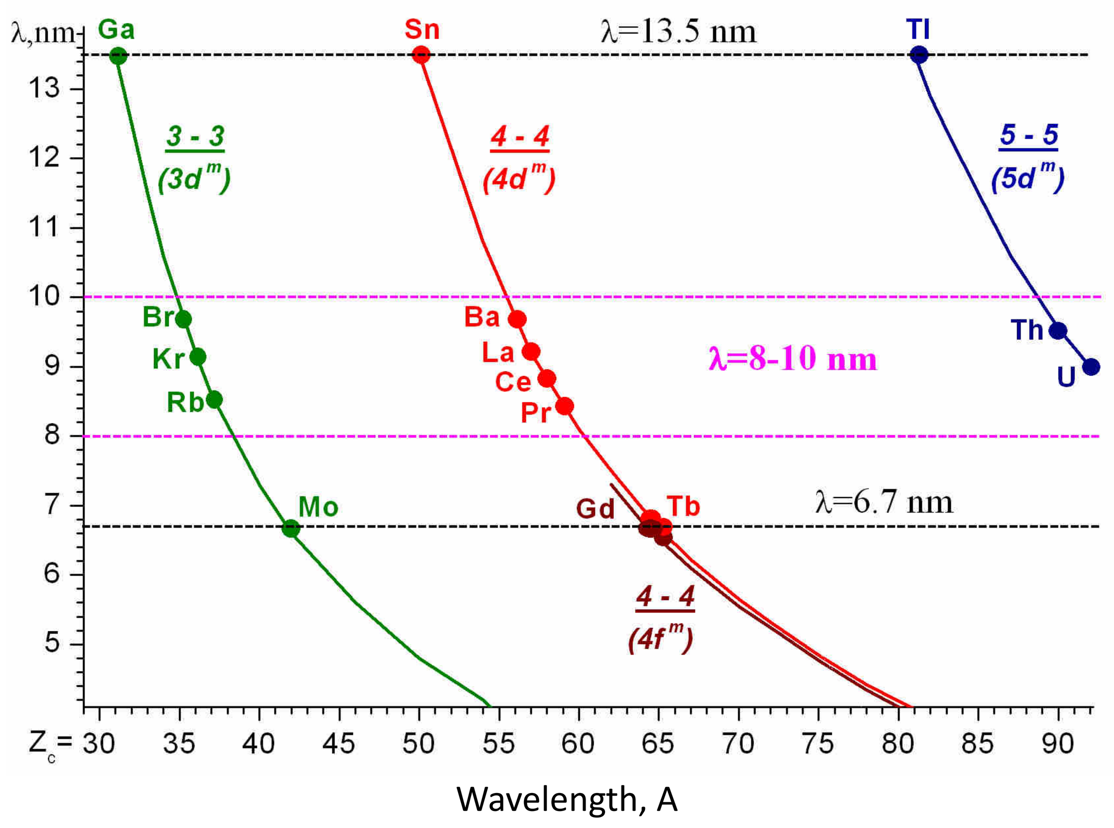
- Imaging at smaller nodes in single exposure
- 2-times higher depth of focus for the same imaging node as compared to 13.5 nm lithography systems
- Higher transparency for C, O_2, H_2, Ar than for 13.5 nm radiation

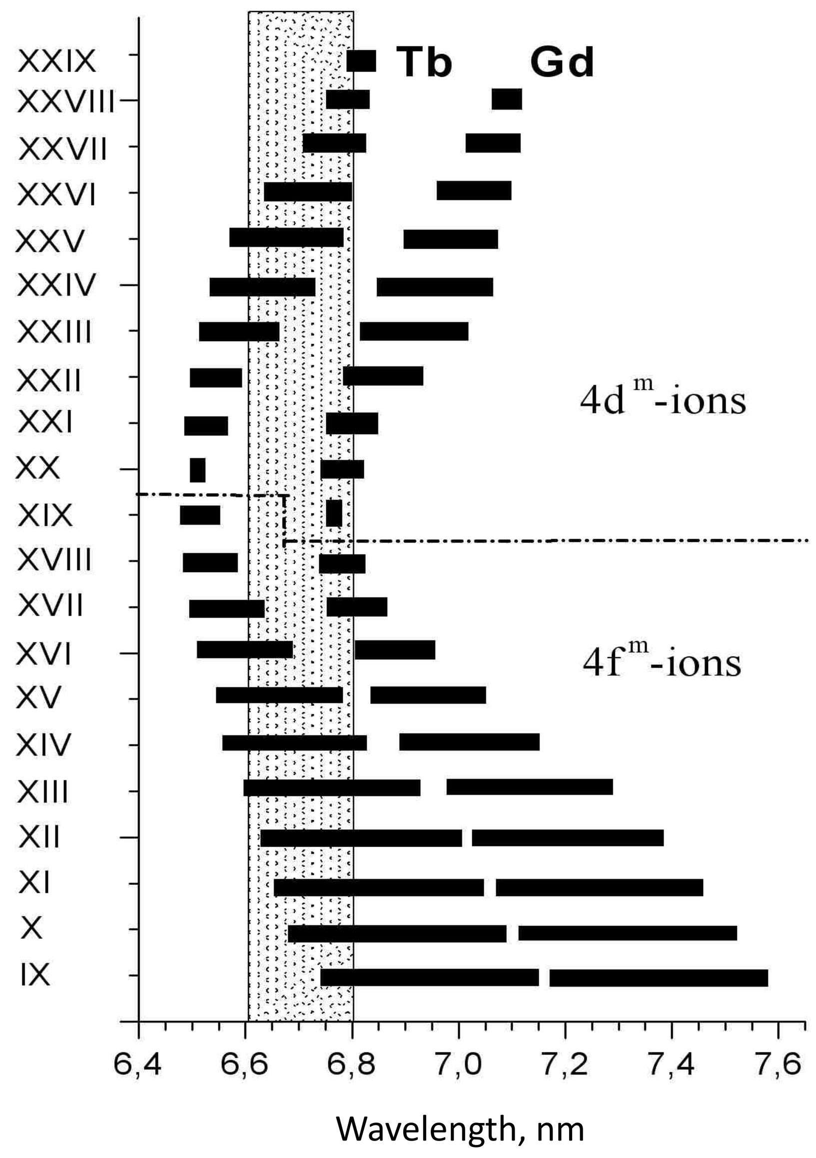
Challenges for 6.x nm lithography

- High reflectance multilayer optics
- High power radiation source
- New resists sensitive for 6.x nm radiation

Choice of fuel

Isoelectronic ion sequences

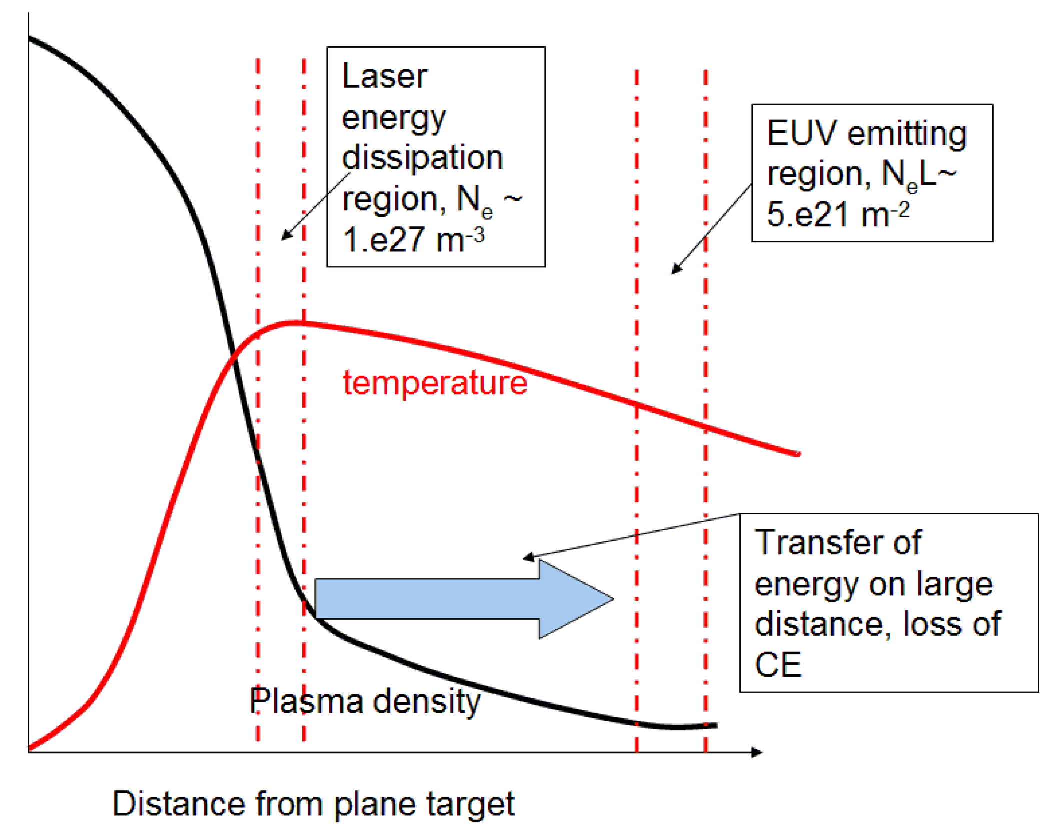




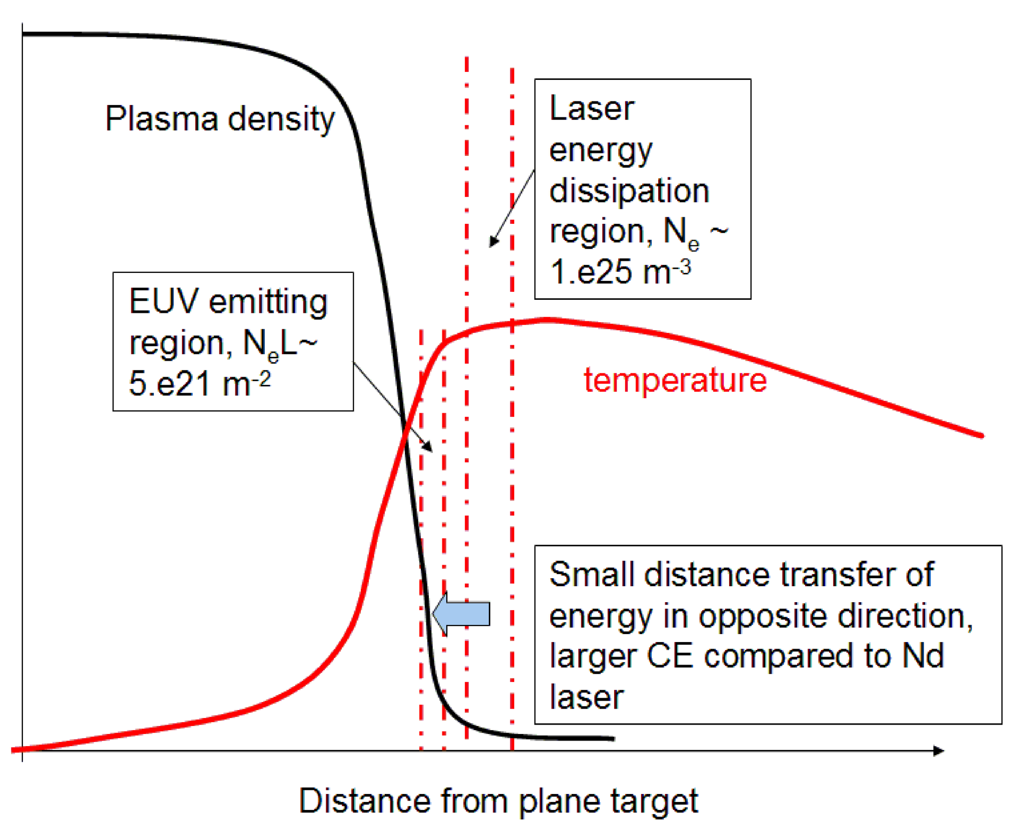
Positions of strong resonance arrays of almost 20 ions with different stages of ionization are concentrated in a narrow spectral range – 6.5-7.2 nm for Tb and 6.7-7.5 nm for Gd.

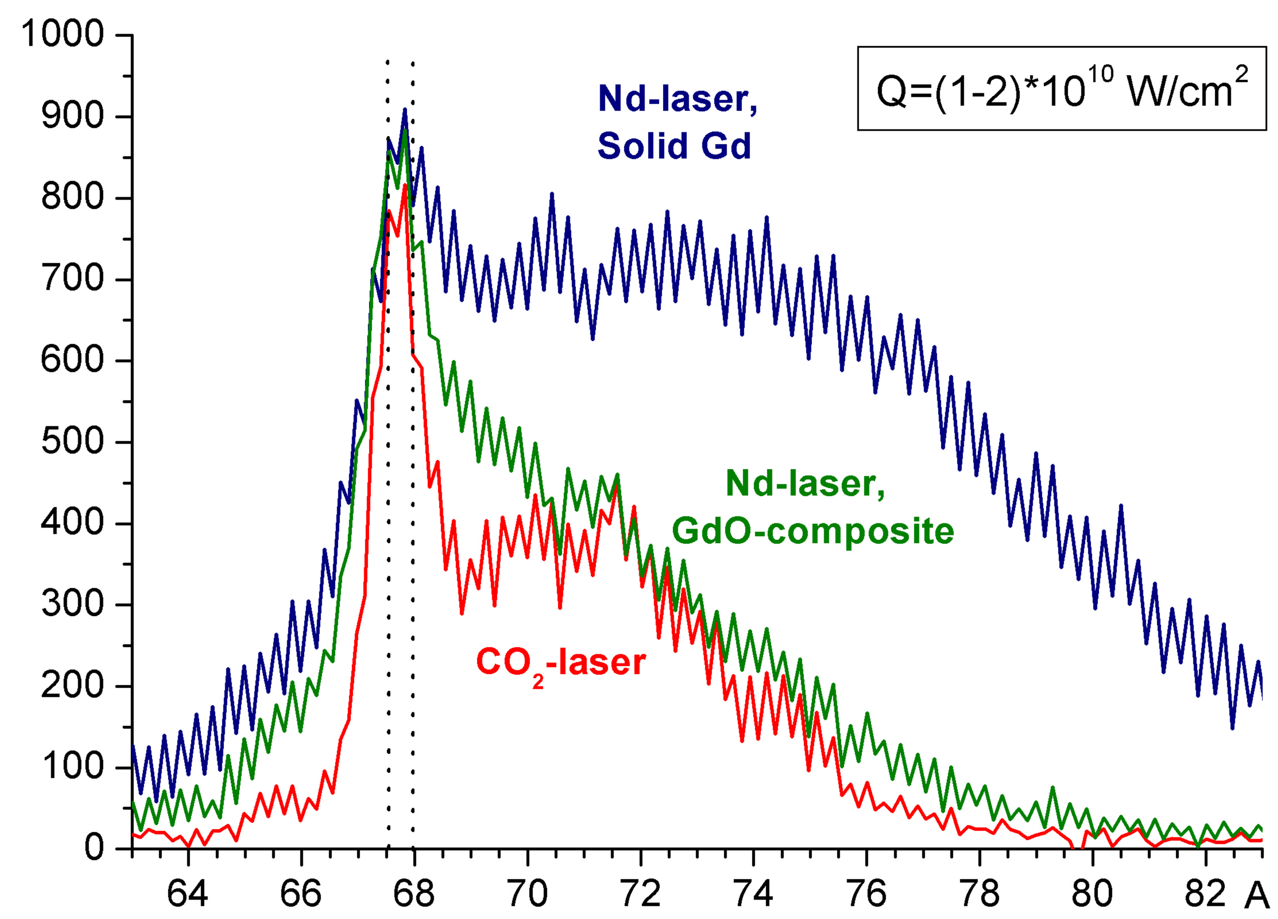
Laser-produced plasma radiation source: Choice of the laser wavelength

Plasma density distribution along laser beam for Nd laser, 1.06 um



Plasma density distribution along laser beam for CO_2 laser, 10.6 um





CO_2 laser radiation is absorbed in the plasma region which is closer to the EUV emitting region → lower energy losses

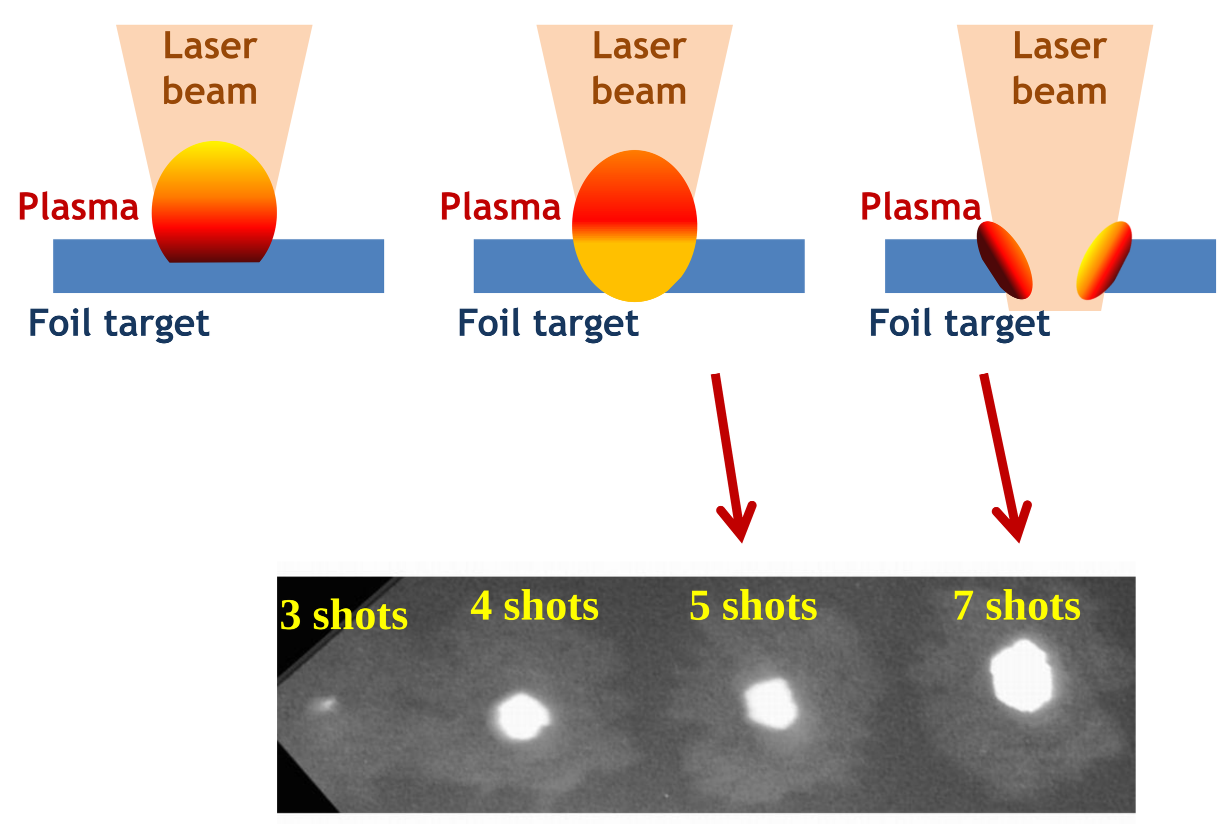
CO_2 laser radiation → lower density plasma → higher spectral purity of the emitted EUV radiation

Tailoring target

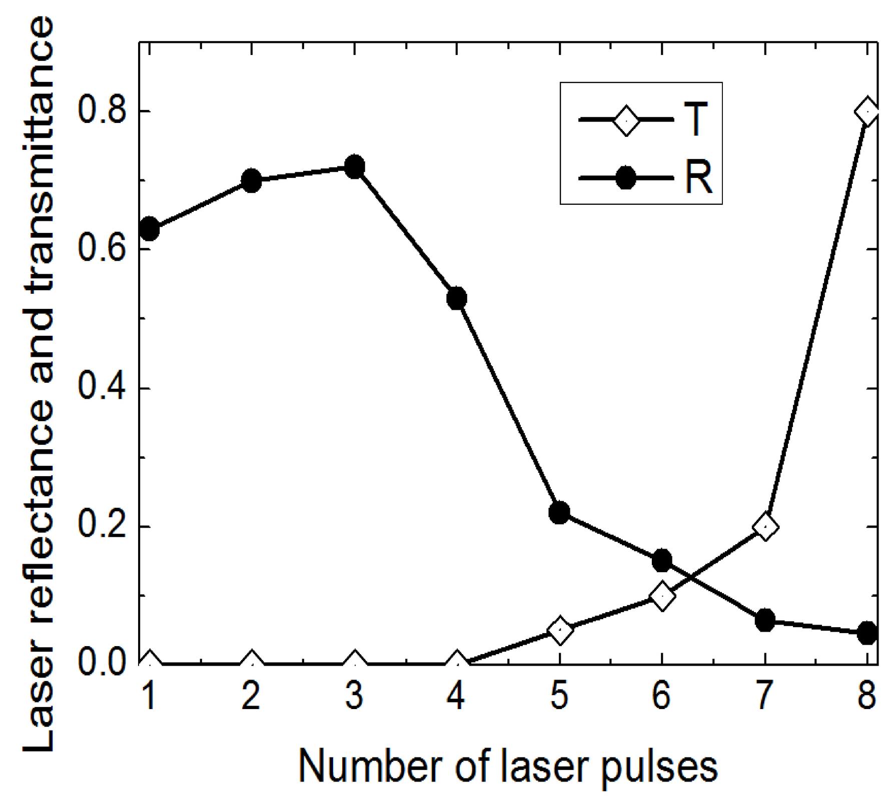
Optimization of conversion efficiency (CE) from CO_2 laser radiation to the useful 6.7 nm radiation requires the production of plasma with low opacity for 6.7 nm radiation and optimization of laser light absorption in plasma

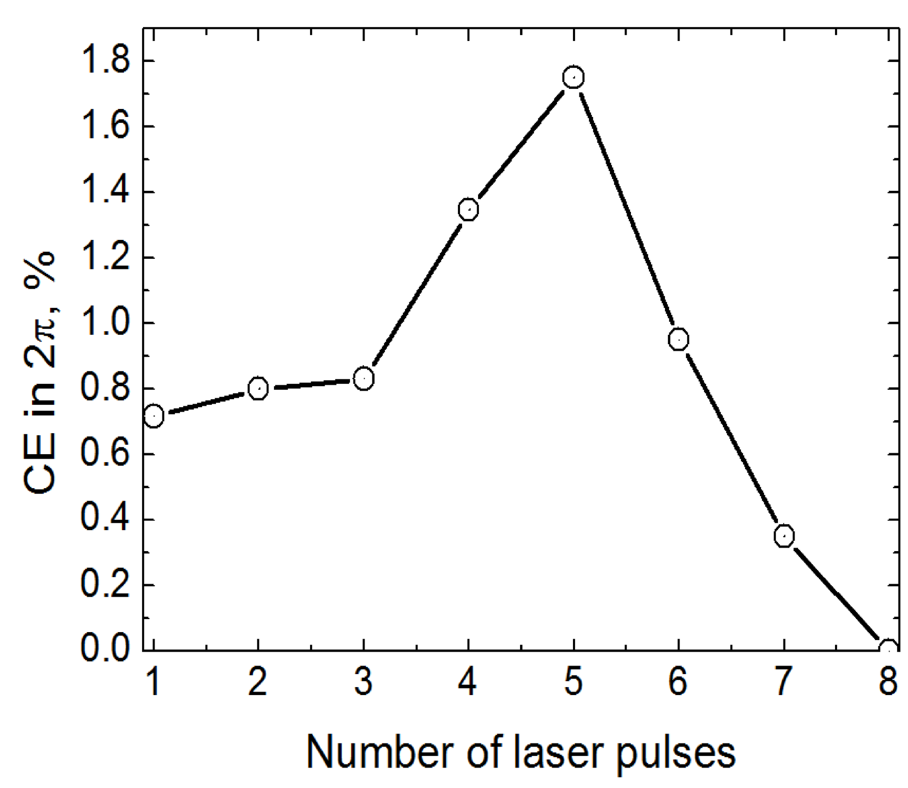
Perforation of the foil Gd target with repeated laser pulses allows to modify plasma expansion geometry:

- Smooth plasma density gradient along laser axis results in the increase of laser light absorption
- Lower plasma density in laser plume results in low optical opacity for the useful 6.7 nm radiation



Experimental results





Summary

- CO_2 laser driven plasma sources of 6.x nm radiation possess significantly higher spectral purity as compared to YAG:Nd laser driven plasmas
- Repeated irradiation and consequent perforation with laser radiation of Gd foil targets provides
  a. Increase of laser absorption by plasma as compared to plane target due to smoother density gradients
  b. 2x increase of 6.7 nm radiation yield due to lower plasma opacity